

# UPPER RIO GRANDE WATER OPERATIONS MODEL

## Forecast Model Documentation

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## 1.0 INTRODUCTION

In April 1998, the Upper Rio Grande Water Operations Model (URGWOM) Steering Committee adopted the recommendation of the Technical Team that RiverWare®, developed by the Center for Advanced Decision Support for Water and Environmental Systems (CADSWES) within the University of Colorado at Boulder, was capable of simulating the complex river and reservoir system that composes the Upper Rio Grande Basin.

Since April 1998, the URGWOM technical team has worked to develop four interrelated modules and an associated database to be used for modeling the upper basin. These four URGWOM modules have become known as the Water Operations Model, Accounting Model, Planning Model, and Forecast Model.

- The Water Operations Model is used to set reservoir releases using “rules” of the policies and authorization that govern releases from reservoirs and to provide information throughout the river system, including San Juan-Chama contractor water and Rio Grande water movements and storages.
- The Accounting Model is replacing the FORTRAN water accounting programs that have been used by the Bureau of Reclamation (USBR) to account for the delivery, use, and storage of San Juan and Rio Grande waters within the basin.
- The Planning Model is an offshoot of the Water Operations Model. It will be used as a predictive model for planning and running multiple scenarios and will be an important tool for Upper Rio Grande Water Operations Review and Environmental Impact Statement (URGWOPS) studies. The number of San Juan contractors in the model is reduced to make running long periods of analysis (20-30 years) more efficient and timely. Additional rules will be developed to allow more alternatives.
- The Forecast Model is designed to develop runoff daily hydrographs for portions of the basin; these hydrographs are based on March–July volumetric forecasts developed by the Natural Resources and Conservation Service (NRCS) for various points within the basin. These hydrographs are exported to the Water Operations and Accounting Models to assist in projecting future operations and in planning the movement of San Juan-Chama and native (Rio Grande) water throughout the system. The Forecast Model also sets data for other slots, such as diversions, wastewater returns, drain flows, precipitation, etc., for use in the Water Operations and Accounting Models.

The Forecast Model is a rather simple way of forecasting future values on the basis of historical data. Some of the functionality of the Forecast Model likely will be replaced in the future with more sophisticated or scientific methods of forecasting such as the U.S. Geological Survey (USGS) Modular Modeling System (MMS) or the U.S. Army Corps of Engineers (Corps) Water Management System (CWMS).

This document describes the procedures used for setting up the Forecast Model for running, testing, and validating the Forecast module of URGWOM and discusses the results obtained during this testing phase. Included in this document are descriptions of methods used in the development and operation of this module, NRCS runoff forecasts, testing methods, and the suite of tests used to validate this module and a summary of the results of the testing suites conducted.

Note: This document does not test the accuracy of NRCS streamflow forecasts. It merely verifies that the Forecast Model's disaggregation of NRCS runoff period volumes to daily hydrographs is correct.

## 2.0 DESCRIPTION OF RUNOFF FORECASTS AND RUNOFF FORECAST MODEL

### 2.1 National Resources Conservation Service Runoff Forecasts

Much of the information in this subsection is quoted and paraphrased from the foreword to the NRCS Western U.S. Water Supply Outlook Report, which can be viewed at:

<http://www.wcc.nrcs.usda.gov/water/quantity/foreword.html>.

Each year, the NRCS publishes a monthly series of reports summarizing the water supply outlook for each of the Western States as well as that of the Western United States region. These Western U.S. Water Supply Outlook reports typically contain a streamflow forecast for upcoming spring runoff, a summary of snow accumulation to date, and a reservoir summary for larger reservoirs in the area. The outlook report for each Western State is published during the first week of each month in which a report is issued and released for each month from January through May or June, depending on the State. For example, the snowmelt and spring runoff patterns in Montana and Idaho warrant reports through June, whereas the snowmelt and spring runoff patterns in New Mexico warrant reporting through only May.

Most usable water in the Western States originates as mountain snowfall. This snowfall accumulates during winter and spring, several months before snow melts and appears as streamflow. Because runoff from precipitation as snow is delayed, snowmelt runoff can be estimated well in advance. Fall precipitation influences soil-moisture conditions prior to formation of the snowpack and determines, in part, the effectiveness of the snowpack in producing runoff.

The forecasts of natural runoff in the NRCS outlook reports are based principally on measurements of precipitation, snowmelt equivalent, and antecedent runoff. Forecasts become more accurate as more of the data affecting runoff are measured. All NRCS forecasts assume that climatic factors during the remainder of the snow accumulation and melt season will interact, with a resultant average effect on runoff. Because of this assumption, early season forecasts are subject to a greater change than those made on later dates. Runoff forecasts in the NRCS outlook reports are listed for what the NRCS terms "forecast points." Forecast points chosen by the NRCS are typically locations such as well-known gaging stations, reservoir inflows, or larger tributary inflows into major river reaches. The streamflow forecasts themselves are typically reported as runoff volumes, in thousands of acre-feet, for the spring runoff season; for most forecast points in New Mexico, the spring runoff season is March through July. For example, a typical outlook report for New Mexico might list a March through July runoff volume at the Otowi gage on the Rio Grande as "1250." This means that the total volume of unregulated streamflow that is forecast to flow by this gage March through July is 1.25 million acre-feet. Part of a typical outlook report for New Mexico is shown in **table 1**.

Precipitation and snowfall accumulation of known probability, as determined by analysis of past records, is used to prepare probability runoff forecasts. The forecasts include an evaluation of the standard error of the prediction model. The forecast runoff volumes are presented at three levels of probability:

Most probable forecast: Given the current hydrometeorological conditions to date, this is the best estimate of what the actual runoff volume will be this season. This is the seasonal runoff that has a 50-percent chance of exceedance.

Reasonable maximum forecast: Given current hydrometeorological conditions, this seasonal runoff volume has a 10-percent chance of being exceeded.

Reasonable minimum forecast: Given current hydrometeorological conditions, this seasonal runoff volume has a 90-percent chance of being exceeded.

**Adjustments:** Runoff forecasts at all points are for full natural or unimpaired runoff corrected for evaporation, upstream diversions, and other hydrologic changes as they develop. Refer to USGS Water-Supply Papers for detailed information concerning diversions and adjustments at the various forecast points. NRCS snowmelt runoff forecasts are often referred to as “unregulated runoff forecasts.”

**Table 1. Part of a typical NRCS Water Outlook Report for New Mexico**

RIO GRANDE BASIN							
Streamflow Forecasts - April 1, 2000							
=====							
	<=== Drier ===		Future Conditions		=== Wetter ===>		
Forecast Pt	===== Chance of Exceeding * =====						
Forecast	95%	70%	50% (Most Prob)	30%	5%	30-Yr Avg	
Period	(1000AF)	(1000AF)	(1000AF) (% AVG.)	(1000AF)	(1000AF)	(1000AF)	(1000AF)
=====							
El Vado Reservoir Inflow							
MAR-JUL	63	80	112	50	144	190	223
APR-JUL	57	72	101	49	130	173	206
Rio Grande at Otowi Bridge							
MAR-JUL	186	241	330	48	489	723	686

\* 90%, 70%, 30%, and 10% chances of exceeding are the probabilities that the actual volume will exceed the volumes in the table.

The average is computed for the 1961-1990 base period.

The value is natural volume - actual volume may be affected by upstream water management.

## 2.2 URGWOM Runoff Forecast Model

The Forecast Model is designed for developing snowmelt-runoff daily hydrographs for portions of the Rio Grande Basin; these hydrographs are based on March-July (April-July for San Juan River) volumetric forecasts developed by the NRCS for various points within the basin. These daily hydrographs, along with data for other slots such as diversions, wastewater returns, drain flows, precipitation, etc., are exported to the Water Operations, Accounting, and Planning Models to assist in projecting future operations and in planning the movement of San Juan and Rio Grande water through the system.

The model has as input each of the historical data parameters needed for the other models for 1985 through 1996. These historical data are used to project future hydrology and data inputs for the other models. When other periods of historical data for each parameter are available, the model can be updated to include a larger dataset to provide a greater sample of climatically related data.

The Forecast Model was developed using the RiverWare software program. RiverWare uses data objects to store historical data and computed forecast data parameters. A ruleset was developed to compute forecast parameters on the basis of historical data. A ruleset is an aggregation of the operating logic and policy that affect the system modeled in RiverWare. A workspace layout of the Forecast Model is shown in **figures 1-3**.

**Figure 1** shows the data objects that contain the historical data. The computed forecast data are output to the data objects shown in **figure 2**. **Figure 3** shows the reach objects and reservoir objects that contain Rio Grande storages and flows that have occurred up to the date of the forecast run. The data in the objects in **figure 3** are explained in later paragraphs.

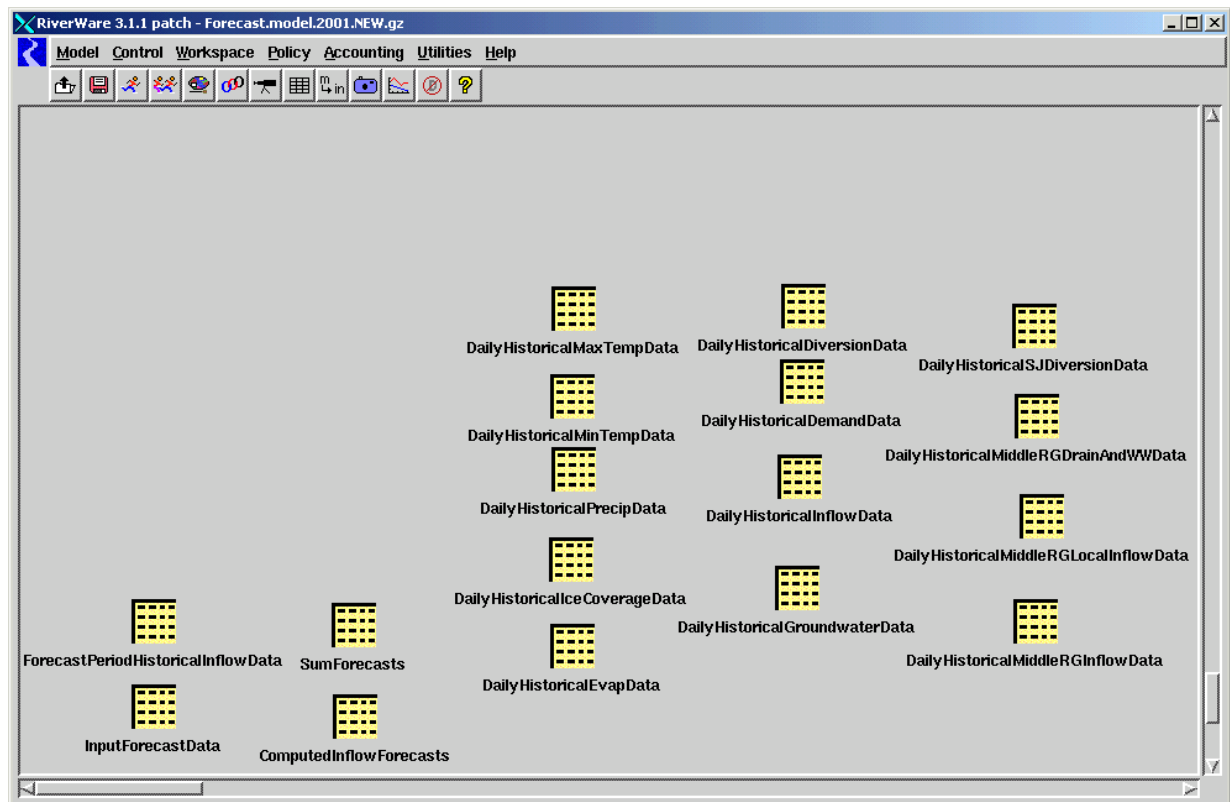


Figure 1. Forecast Model workspace layout – historical data objects.

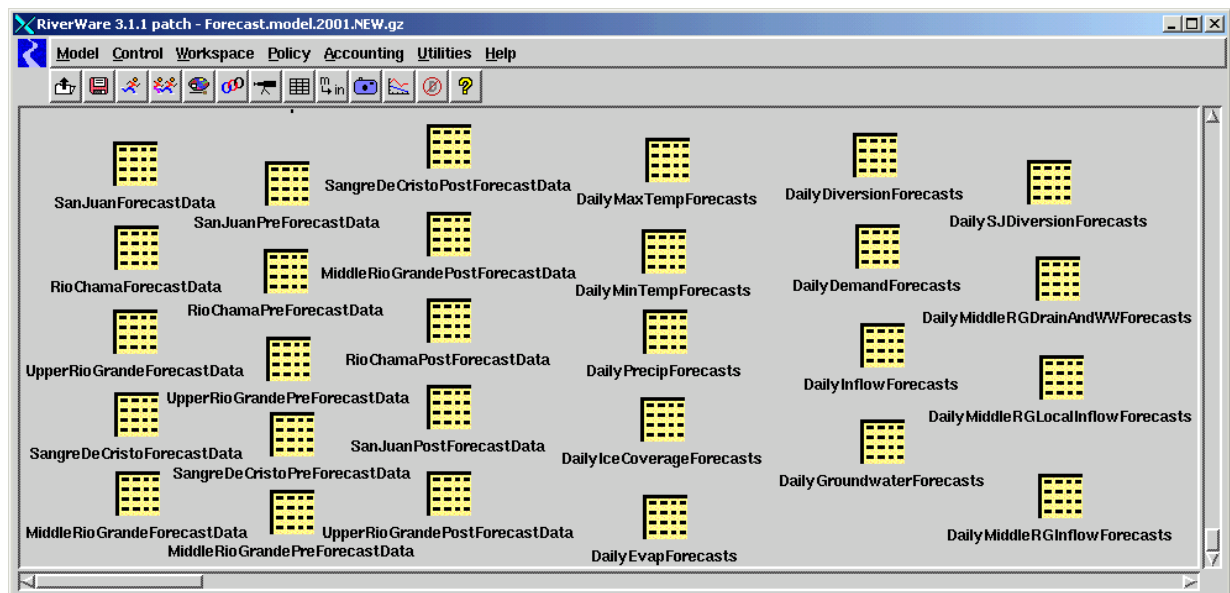
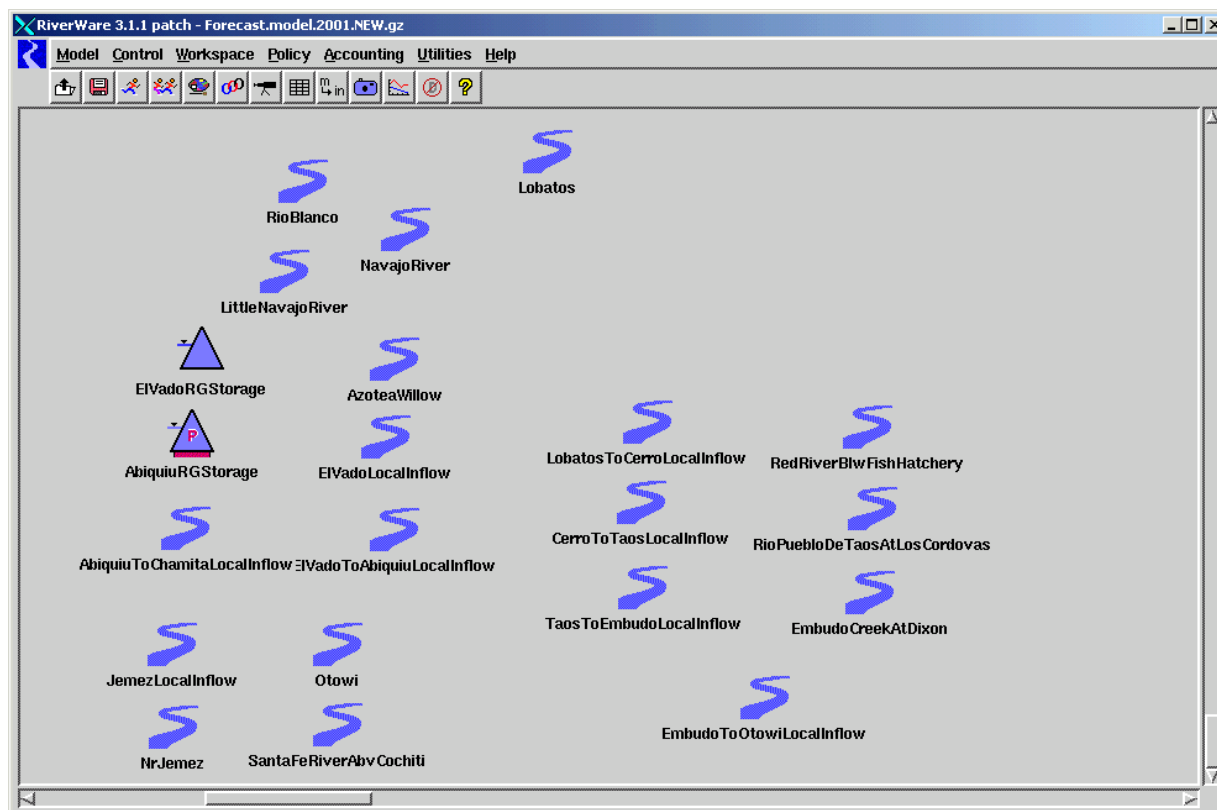


Figure 2. Forecast Model workspace layout – forecast data objects.



**Figure 3. Forecast Model workspace layout – Rio Grande storage and point inflow objects.**

**Figure 4** shows the input forecast data object when it is opened, displaying the table slots that have been filled or need to be filled when a forecast run is prepared. Input for this model includes the NRCS forecast runoff volumes for 11 forecast points, number of years to average parameters during the snowmelt-runoff season, distribution of runoff and local inflow within the snowmelt runoff, coefficients and constants for the linear regression equation that relates runoff on the Little Navajo River to that on the Navajo River, average losses for the runoff period, starting date of forecasts, blending ratio, number of years to average parameters during the pre-forecast period, and number of years to average parameters during the post-forecast period. All these data can be input into slots set up in the model, as seen in **figure 4**.

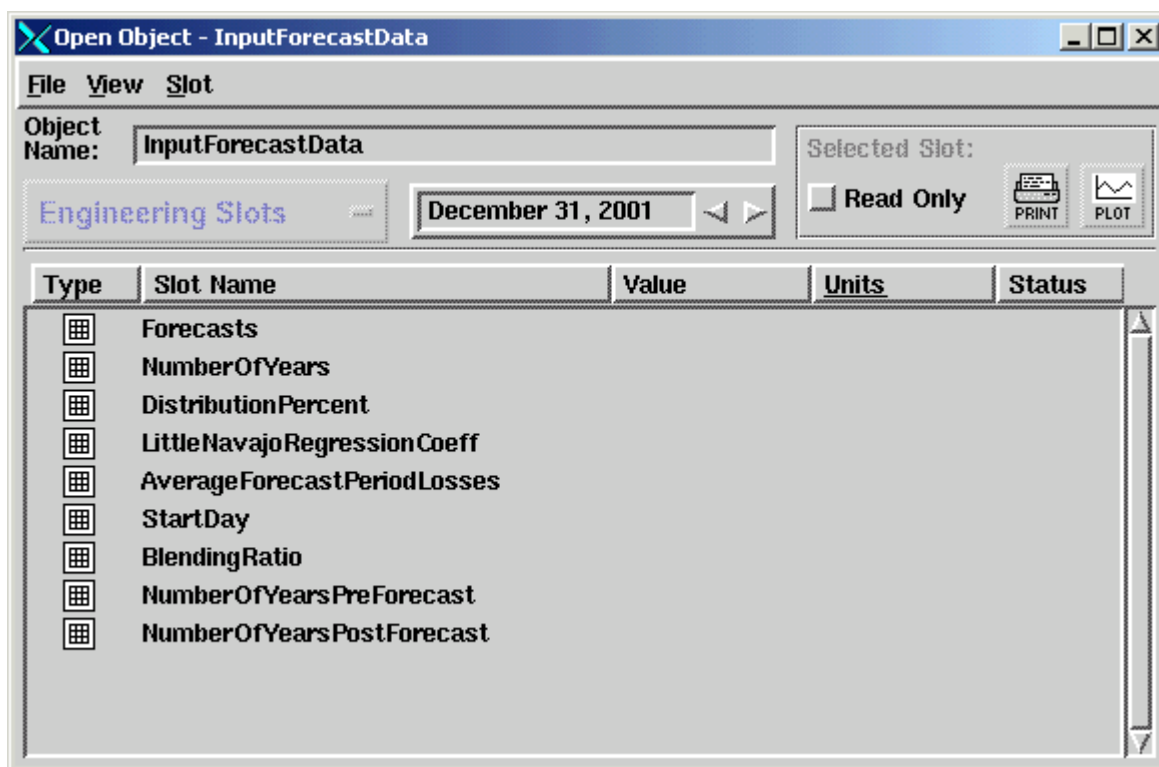


Figure 4. Slots for Forecast Model.

### Forecasts

Examining the required input data shown in **figure 4** in greater detail is important. This discussion and the following description of the model are intended to be brief, yet still provide an adequate description of the functionality of the Forecast Model. The Forecast Model ruleset contains the logic used.

A maximized view of the Forecasts slot shown in **figure 4** can be seen in **figure 5**. This slot takes the shape of a table with 5 columns and 11 rows for data entry.

With the exception of row 0, Lobatos, the rows in **figure 5** list forecast points used by the NRCS in their runoff forecasts. The State of Colorado will provide data entered into the Lobatos cell that represent their projected Rio Grande Compact deliveries to the New Mexico State line. Each column represents the monthly NRCS forecast issued for the particular year that the model is examining. The data contained in this slot are updated as each new forecast is issued. After the updated data are entered into the model, the model is run again to update the projected runoff hydrographs.



The screenshot shows a window titled "Edit InputForecastData::Forecasts". It has a menu bar with "File", "Edit", and "View". Below the menu bar, there are two input fields: "Name:" with the value "Forecasts" and "Value:" with the value "50.00". Below these fields is a table with 5 columns representing months (January, February, March, April, May) and 13 rows representing different locations. Each column header is followed by "1000acre-feet". The table data is as follows:

	January 1000acre-feet	February 1000acre-feet	March 1000acre-feet	April 1000acre-feet	May 1000acre-feet
Lobatos 0	50.00	50.00	50.00	50.00	50.00
RedRiverBlwF1	19.50	17.00	17.00	26.00	17.40
RioPuebloDeT:2	13.50	11.50	12.00	21.00	12.00
EmbudoCreek/3	17.50	17.50	17.50	25.00	15.20
Otowi 4	290.00	200.00	230.00	330.00	260.00
SantaFeRiver/5	2.60	1.60	1.60	2.10	1.50
Jemez 6	15.60	10.00	10.00	15.20	11.90
TotalJemezInfl7	14.50	6.50	6.50	12.80	10.20
ElVado 8	113.00	70.00	77.00	112.00	96.00
RioBlanco 9	30.00	20.00	27.00	30.00	22.00
NavajoRiver 10	34.00	20.00	34.00	33.00	27.00

**Figure 5. Input data required for the Forecasts slot within the input forecast object contained in the Forecast Model.**

Two of the forecast points listed in **figure 5** are recent additions to the NRCS reporting system. The forecast point listed in row 3 of **figure 5**, Embudo Creek at Dixon, was added in 1999 at the request of the URGWOM steering committee. In addition, the NRCS added the forecast point listed in row 7, Jemez Reservoir inflow, in 1998 (**fig. 5**).

### Number of years

A maximized view of the NumberOfYears slot listed in the InputForecastData slot is shown in **figure 6**. This slot contains a 13-row by 5-column data table. The rows are labeled with physical variables that the model uses to generate runoff hydrographs. The columns break down the data into the five basins affecting runoff and operations within the Rio Grande Valley. The data entered into this table are best described by the slot's title. The user enters a value from 1 to the number of years (currently as many as 12 years can be selected) of historical data into each of the table's cells. This entry represents the number of closest years of each of these physical parameters the model will use to generate a runoff hydrograph and other parameters. In other words, if the user enters a value of 1 in the (MaxTemp, Rio Chama) cell, the model will pull up the closest year of maximum temperature data from its database and use these data to assist in simulating runoff conditions in the Rio Chama Basin. However, if the user entered a value of 3 into this cell, the model would pull up the closest 3 years (as determined by the runoff forecasts) of maximum temperature data from its database, average the values each day, and use the results to simulate runoff conditions in the Rio Chama Basin.

		San Juan	Rio Chama	Upper Rio Grande	Sangre De Cristo	Middle Rio Grande
		NONE	NONE	NONE	NONE	NONE
Inflow	0	1.00	1.00	1.00	1.00	1.00
MinTemp	1	3.00	3.00	3.00	3.00	3.00
MaxTemp	2	3.00	3.00	3.00	3.00	3.00
Evap	3	3.00	3.00	3.00	3.00	3.00
Precip	4	3.00	3.00	3.00	3.00	3.00
Demand	5	3.00	3.00	3.00	3.00	3.00
Diversion	6	3.00	3.00	3.00	3.00	3.00
MiddleRGInflow	7	3.00	3.00	3.00	3.00	3.00
MiddleRGDrain	8	3.00	3.00	3.00	3.00	3.00
MiddleRGLoca	9	3.00	3.00	3.00	3.00	3.00
IceCoverage	10	3.00	3.00	3.00	3.00	3.00
Groundwater	11	3.00	3.00	3.00	3.00	3.00
SJDiversions	12	3.00	3.00	3.00	3.00	3.00

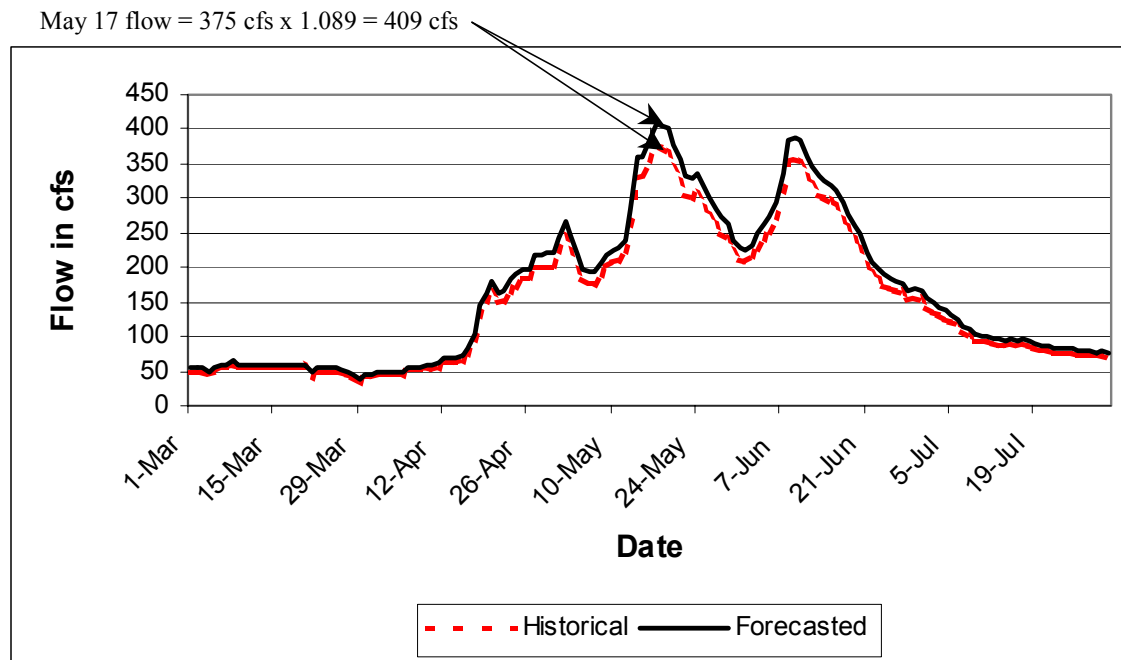
**Figure 6. Input data required for the NumberOfYears slot within the input forecast object contained in the Runoff Forecast Model.**

Note that the term “closest year” refers to the year in the database for which forecast runoff volume data most closely match the data of the year currently being simulated by the model. The “Set Closest Year” rule makes use of the input to the NumberOfYears slot to generate the desired data.

The concept of “closest year” and disaggregation of the NRCS runoff period volume to daily flows needs further explanation. The NRCS forecast volume is compared to historical hydrograph volumes for the same forecast period (March-July) to determine which historical year is the closest for use as a “template” or “unit” hydrograph to generate daily flows. The assumption used in this approach is that a year with runoff volume similar to the current forecast is a fair starting point on the expected manner in which the forecast volume will run off this time. The shape of the closest year hydrograph is then used to disaggregate the total volume of the forecast to daily flows. Of course, the forecast volume will not exactly match any historical volumes, so the historical daily flows are adjusted by the ratio of the forecast volume to the historical volume to match the forecast volume for the period. If more than 1 closest year is selected, the model averages the values for each day of the closest years, then adjusts the resulting values to match the forecast volume. An example of adjusting the historical hydrograph to match the forecast volume is shown in **figure 7**.

Users also have the ability to manually select the closest year(s) (overriding the rule) because they may prefer other historical hydrograph shapes rather than the one that is closest in volume. This is done by inputting the desired year in the forecast data objects shown on the left side of **figure 2**.

The NumberOfYears table is for setting the number of years to average for the forecast period (March-July). Two similar tables (NumberOfYearsPreForecast and NumberOfYearsPostForecast) also require input to set the number of years before (January-February) and after (August-December) the forecast period. These tables are set up in the same manner as the table in **figure 6**.



Mar-July Forecasted Volume = 50,000 acre-feet

Mar-July Historical Volume = 45,913 acre-feet

Ratio = 50,000/45,913 = 1.089

Forecasted flow = Historical flow x Ratio

**Figure 7. Example of adjusting historical hydrograph to match forecast volume.**

The Accounting Model may require data that are not readily available, such as diversion, wastewater, missing gage data, which must still be input into the Accounting Model to perform a run. The Forecast Model can be used to “fill in” these parameters that are not yet available with realistic estimates to allow the accounting simulation to run. The “pre-forecast” rules allow the Forecast Model to fill in data prior to the forecast period using the latest forecast. For example, the Forecast Model is set up to run a March NRCS forecast that is significantly different from the February forecast; thus, the pre-forecast rules will fill in data for January and February on the basis of the new forecast. If users are not concerned with generating data prior to the date of the forecast, they simply begin the run on the date of the forecast (for example, set the start time of the run for the March forecast to begin on March 1).

The Forecast Model can also generate forecasts of data parameters for the time period after the NRCS forecast of March-July, using the “post-forecast” rules to generate the data for August-December. The pre- and post-forecast rules do not adjust daily flows; they simply use actual historical data (or average if more than 1 closest year) as the forecast data.

Note that users are given a fair amount of flexibility to generate forecast data for several time periods throughout the year. This requires that users understand the model and the input needed to achieve the desired results.

### Distribution percent

A maximized view of the DistributionPercent slot contained within the input forecast object is shown in **figure 8**. Unlike the other slot titles contained in the input forecast data object, the significance of the data contained in this slot may not be readily apparent. Although a goal of this report is to be as brief as possible, the logic and programming statements that use these data need to be explained so that the user

may fully understand how the data contained in this slot are used. Much of the following explanation was taken from programming comments written by Brad Vickers of Wave Engineering and is in the rules code. Some rules have been added but not noted (such as the pre-forecast and post-forecast rules and functions), some have been slightly modified by the URGWOM technical team since the programming comments were written by Wave Engineering, and some programming comments require updating. The following discussion focuses on the “distribute forecasts” rule and ultimately explains the significance of the data in the DistributionPercent slot.

	DistributionFractic	decimal
ElVadoToAbiquiuLocalInflow	0	0.160
AbiquiuToChamitaLocalInflow	1	0.220
AzoteaWillow	2	0.060
LobatosToCerroLocalInflow	3	0.070
CerroToTaosLocalInflow	4	0.180
TaosToEmbudoLocalInflow	5	0.020
EmbudoToOtowiLocalInflow	6	0.350
LocalInflowReduction	7	0.029

**Figure 8. Input data for the DistributionPercent slot within the input forecast object contained in the Forecast Model.**

Although the user inputs data for 11 NRCS forecast points into this model, 19 forecast points are needed to successfully run the Water Operations Model. This transformation takes place within the “distribute forecasts” rule. This rule uses the information in the InputForecastData slot to determine the total March-July forecast for each of the 19 locations required by the Water Operations Model. This particular rule also uses the input forecast for the Navajo River and Rio Blanco forecast points to determine a projected runoff volume and its distribution for the Little Navajo River, which is not currently forecast by the NRCS. One of the purposes of this rule is to split the forecast of El Vado Reservoir inflow into two components: (1) Rio Grande inflow into Heron Reservoir (which is assumed to be released into El Vado because storage of water native to the Rio Grande Basin is not allowed to be stored in Heron) and (2) local inflow, or runoff, between Heron and El Vado Reservoirs plus additional snowmelt runoff originating in the Rio Chama Basin. After El Vado inflow is divided into two components, the logic contained in the rule then forces the model to determine the total local inflow within the Rio Grande Basin and distributes it into six locations. These six locations, as they are referred to in the model, are:

ElVadoToAbiquiuLocalInflow,  
 AbiquiuToChamitaLocalInflow,  
 LobatosToCerroLocalInflow,  
 CerroToTaosLocalInflow,  
 TaosToEmbudoLocalInflow, and  
 EmbudoToOtowiLocalInflow,

These operations and calculations within the model provide the required 19 inflow points for export to the Water Operations Model.

One other method must be explained in greater detail concerning the significance of the DistributionPercent slot. In the Rio Grande Basin above Otowi, the NRCS or State of Colorado provides forecasts of inflow for five locations: Lobatos, Red River below Fish Hatchery, Rio Pueblo de Taos near Los Cordovas, Embudo Creek near Dixon, and El Vado Reservoir. Along with these forecast points, the NRCS provides a projected runoff volume at Otowi; thus, the portion of runoff that enters the system between these forecast points and Otowi can be indirectly computed. To compute the total contribution that this local inflow has on the forecast of flow at Otowi, each of the provided forecasts must be routed (inclusive of model losses) to Otowi. In the Water Operations Model, these losses vary monthly. The Forecast Model, however, uses the average of the March-July percent losses in the Water Operations Model to estimate these losses. To compute total Rio Grande local inflow above Otowi, the routed forecasts are subtracted from the Otowi forecast according to the relation:

$$\text{Total local inflow} = (\text{ForecastAtOtowi} - \text{routed}(\text{ForecastAtElVado}) - \text{routed}(\text{ForecastAtLobatos}) - \text{routed}(\text{ForecastAtRedRiver}) - \text{routed}(\text{ForecastAtRioPueblo}) - \text{routed}(\text{ForecastAtEmbudoCreek})) \times \text{adjustment factor}.$$

An adjustment factor in the above equation is needed to compensate for the difference in losses between the monthly losses applied in the Water Operations model and the average losses applied with the Forecast Model. This adjustment factor was determined through analysis to be approximately 2.9 percent.

After total local inflow above Otowi is determined, the amount to distribute to each of the six locations is computed by multiplying total local inflow by the factors within the DistributionPercent slot shown in **figure 8**. These distribution factors were determined by analyzing historical flow, similar to the procedure used to divide El Vado Reservoir forecast inflow. After the distribution is determined, each forecast of local inflow is then routed back upstream (adding losses back in). The net effect of this procedure is the production of a forecast closely matching (within two-tenths of a percent) the forecast flow at Otowi issued by the NRCS. The detail and specifics of how each forecast or local inflow is routed using the following functions are in the ruleset:

TotalLocalInflowForecast  
RoutedRioChamaForecast  
RoutedRioGrandeForecast  
RouteLobatosToCerroLocalInflow  
RouteCerroToTaosLocalInflow  
RouteTaosToEmbudoLocalInflow  
RouteEmbudoToOtowiLocalInflow  
RouteAbiquiutoToChamitaLocalInflow  
RouteElVadoToAbiquiuLocalInflow.

	x1	x2	constant
	decimal	decimal	acre-feet
coeff 0	-0.072	0.188	-951.74

**Figure 9. Input data for the LittleNavajoRegressionCoeff slot within the input forecast object contained in the Forecast Model.**

#### **Little Navajo regression coefficient**

A maximized view of the Little Navajo regression coefficient is shown in **figure 9**. The Little Navajo River at the Little Oso Diversion Dam is not presently included in any runoff forecast. However, there is a very strong relation between flow of the Navajo River and the Rio Blanco to flow in the Little Navajo River. A regression analysis conducted by the URGWOM technical team yielded a correlation coefficient of 0.96 for this relation. The regression coefficients and constant obtained in this study are located in the LittleNavajoRegressionCoeff slot (**fig. 9**). These coefficients are used in the function "LittleNavajoForecast" to determine the forecast for the Little Navajo River. This function represents the relationship:

Mar – Jul Runoff Volume for Little Navajo near Little Oso Diversion Dam =  
 -0.072 (Rio Blanco Mar – Jul Runoff Vol for Rio Blanco abv Blanco Div Dam)  
 + 0.188 (Navajo River Mar – Jul Runoff Vol for Navajo River abv Oso Div Dam) – 951.74.

	Fraction	decimal
ElVadoToAbiqu0	0.046	
AbiquiuToChan1	0.056	
LobatosToCen2	0.042	
CerroToTaos 3	0.056	
TaosToEmbudo4	0.034	
EmbudoToCon5	0.078	
ConfluenceTo6	0.074	
NrJemezToJer7	0.240	

**Figure 10. Input data required for the AverageForecastPeriodLosses slot within the input forecast object contained in the Forecast Model.**

#### **Average Forecast Period Losses**

A maximized view of the AverageForecastPeriodLosses slot is shown in **figure 10**. As stated earlier, projected runoff volumes are routed from the forecast points north of Otowi to the Otowi forecast point. During the March-July runoff season, these losses are averaged within the Forecast Model. These average losses are entered in the AverageForecastPeriodLosses slot seen in **figure 10** and are used to route flows within each of the seven reaches. Row 7 of the data table composing this slot is used to compute additional losses and inflow between the forecast points of Jemez River near Jemez and Jemez Reservoir inflow.

#### **Start Day**

A maximized view of the StartDay slot can be seen in **figure 11**. The data table in this slot consists of a one-row by one-column series and is fairly self explanatory. The start day of the monthly forecast is entered into this slot. At present, RiverWare requires that date references be in the form of the day of the year (DOY). The DOY for any day of a particular year is simply the numerical order of that day in that year. For example, January 1 of any year has a DOY of 1. During a non-leap year, March has a DOY of 60; during a leap year, March 1 has a DOY of 61. During a run of the Forecast Model, the run control is usually kept at a start day of January 1 (**fig. 12**). However, the value input into the StartDay slot has a direct bearing on which NRCS monthly forecast data are used in the model run.

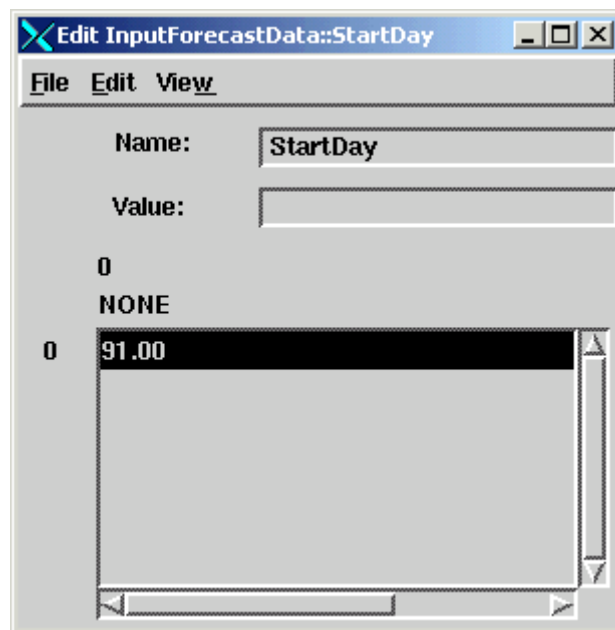


Figure 11. Input data required for the StartDay slot within the input forecast object contained in the Runoff Forecast Model.



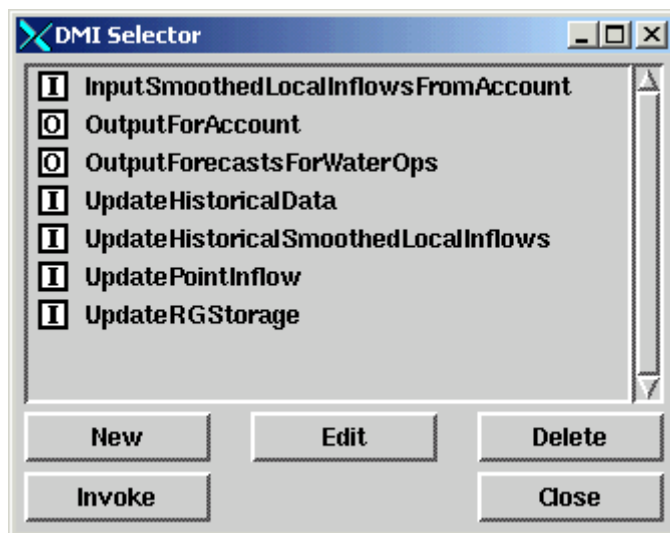
Figure 12. Run control dialog box for the model run associated with the StartDay slot shown in figure 11.



For example, a user attempts to use the model to project runoff hydrographs using the April 1 NRCS forecast. The user sets the start day slot to 91 (see **fig. 11** for a non-leap year) and sets the run control from January 1 through December 31 (**fig. 12**).

A few other items also need to be updated before the user can start the model run. As stated earlier, the four modules of URGWOM exchange information with one another, with each module interdependent on the other three for critical information. In this example, the Accounting Model must be updated to input the Rio Grande storages (to compute the amount of Rio Grande runoff stored in the reservoirs) through the forecast date, April 1 in this example, prior to running the Forecast Model. Once the Accounting Model is updated and compiled, its results are imported into the Forecast Model by invoking the "UpdateRGStorage" data management interface (DMI) shown in **figure 13**. Because reservoir objects are used for computing the Rio Grande runoff captured by El Vado and Abiquiu Reservoirs, initial Rio Grande storages must always be input. Otherwise, the simulation will abort because the initial conditions of the reservoir objects will not be known.

Because the example run has a beginning date of April 1, the actual flow values from January 1 through March 31 must also be imported into the Forecast Model to determine the amount of runoff that has already occurred up to the date of the forecast. This information is required for determining the amount of runoff volume remaining through the rest of the forecast period (April-July). Actual flows up to the date of the forecast are imported by invoking the UpdatePointInflow DMI, also shown in **figure 13**.



**Figure 13. Data management interface selector for the model run associated with the StartDay slot shown in figure 11.**

The UpdateRGStorage and the UpdatePointInflow DMI's import data into the reservoir and reach objects that are shown in **figure 3**.

Leap years can present a small annoyance for the results of the Forecast Model. When forecasting during a leap year and the closest year selected is a non-leap year, the daily data will be offset by 1 day when compared with historical data. The same can also occur when forecasting during a non-leap year and the closest year selected is a leap year. The volumes of the runoff forecasts are not affected by this phenomenon; only the timing of daily flows are offset by 1 day.

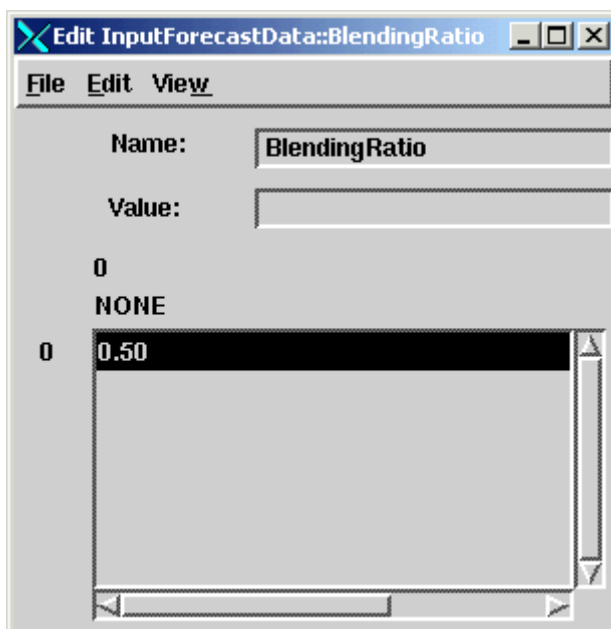
While experimenting with the first few versions of the Forecast Model, users found that some local inflow values imported from the Accounting Model and the database varied greatly on a daily basis. In addition, the values of local inflow would occasionally be negative. To minimize problems such as these, two new functions within the Accounting Model and two new DMI's within the Forecast Model were developed that

allow the user to generate and import smoothed local inflows into the Forecast Model. These DMI's, "InputSmoothedLocalInflowsFromAccount" and "UpdateHistoricalSmoothedLocalInflows," are also shown in **figure 13**.

### Blending Ratio

A maximized view of the BlendingRatio slot is shown in **figure 14**. During the initial testing of the Forecast Model, users noticed a discontinuity between the actual and modeled hydrographs on the first day of the simulation. To give the user the option of modifying this jump from a picture of the actual system to a forecast picture of the system, the concept of blending forecast flows with observed flows was introduced. The blending ratio is a value ranging from 0 to 1.0 that can be determined and entered by the user.

The blending ratio allows the user to specify at which point the ratio of forecast flow to the previous day's observed flow is great enough to blend the hydrograph to reduce a big increase or decrease in flows. For example, a blending ratio of 0.50 tells the model to blend the hydrograph when the absolute value of the ratio of forecast flow to observed flow is equal to or greater than 0.5. If the ratio is equal to or greater than 0.5, the first two values of the forecast flows are adjusted equally (one-third) each day until the flow is equal to the forecast flow on the third day. For example (also shown graphically in **fig. 15**), if the ratio of the forecast flow on April 1 (175 cfs, for example) to the observed flow on March 31 (100 cfs, for example) is greater than the blending ratio in the table ( $175-100/100 = 0.75 > 0.5$ ), then the blending of hydrographs is implemented. The flow on April 3 is 200 cfs, so the difference between the flows on March 31 and April 3 is 100 cfs. The flow on April 1 will be increased by 33 cfs to 133 cfs, followed by another 33-cfs increase on April 2 to 166 cfs; on the third day the flow is the 200 cfs that was forecast for April 3. Using this blending approach slightly alters original forecast flows to match the total volume for the NRCS runoff period; therefore, the forecast daily flows may not sum up exactly to the total volume of the NRCS forecast. If the user does not wish to blend the hydrographs, the blended hydrographs rule can simply be turned off. The user has to weigh the importance of almost exactly matching the NRCS runoff-period volume forecast or avoiding big increases or decreases from the observed flows to the forecast flows.



**Figure 14.** Input data required for the BlendingRatio slot within the input forecast object contained in the Forecast Model.

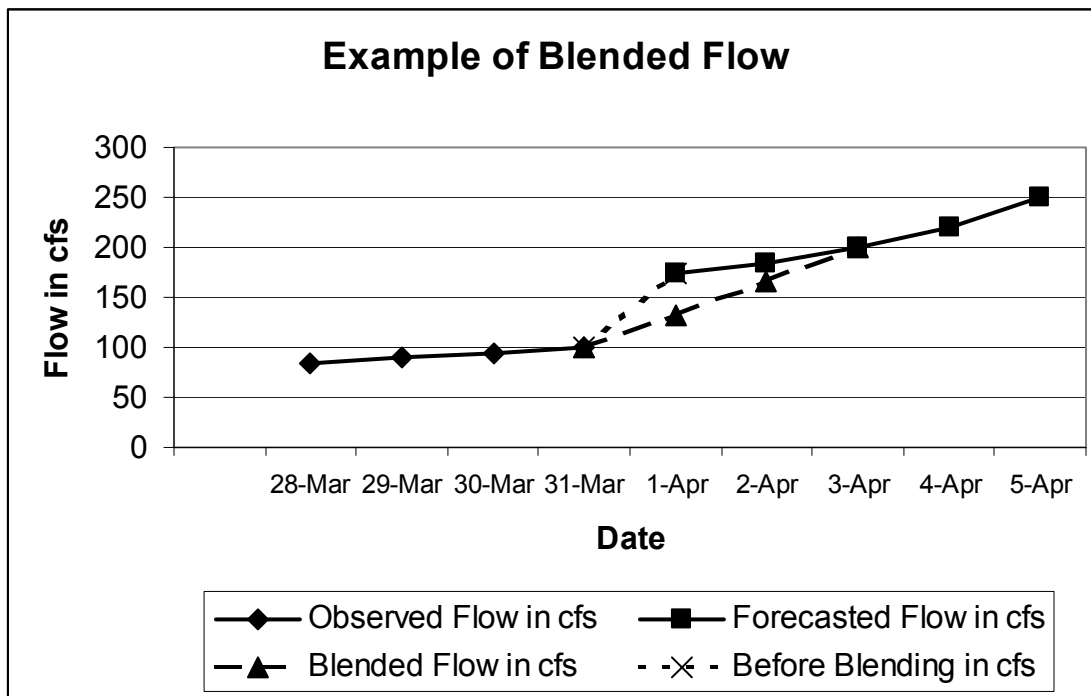


Figure 15. Illustration of a discontinuity between actual and forecast flows.

#### Number of years pre- and post-forecast

The NumberOfYears pre-forecast and NumberOfYears post-forecast slots are used in the same way as the NumberOfYears slot described earlier.

After setting and importing all required data for a Forecast Model simulation run, the user must load a ruleset for the model to compile. The Forecast Model ruleset contains routing methods, loss rates, and data transformation methods and functions, to name a few. An example of the ruleset titled "forecast.ruleset" can be seen in **figure 16**. The ruleset, like any other ruleset contained in a RiverWare model, is loaded by simply clicking the "ruleset not loaded" button in the upper right corner of the ruleset editor window.

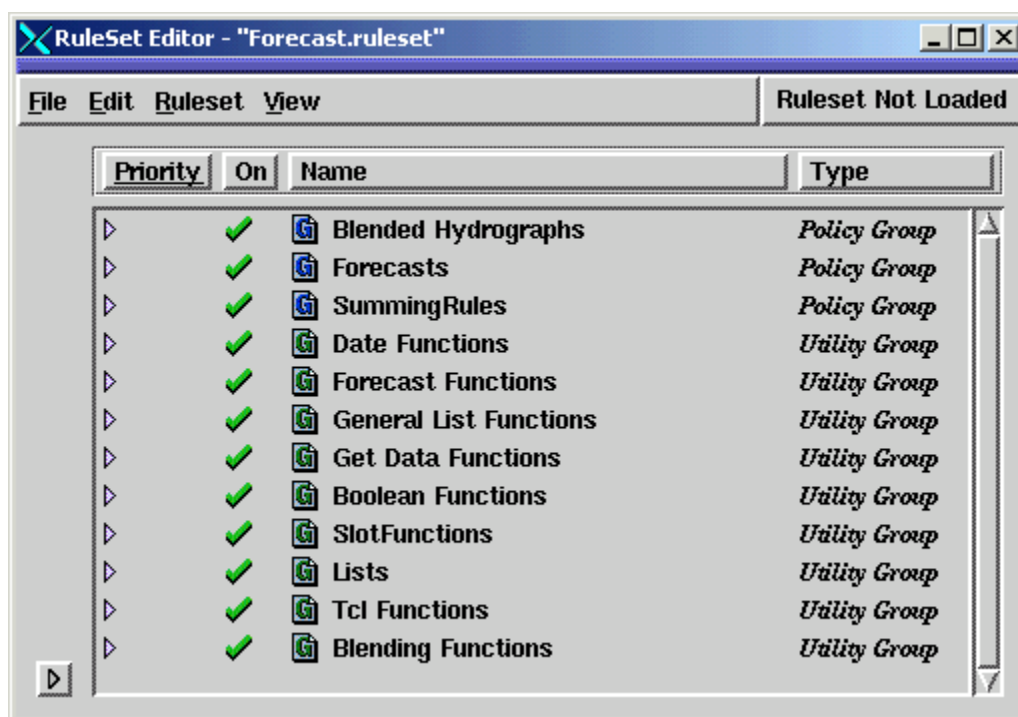


Figure 16. Screen slot of the forecast ruleset used in the Forecast Model.

### 3.0 TEST METHOD

The series of years from 1995 through 1998 was chosen as a study period to test the accuracy of the Forecast Model disaggregation of the volume forecast to daily hydrographs. This period was considered ideal for testing purposes because it offered a fairly wide distribution of NRCS forecast runoff volumes. Every monthly forecast published by the NRCS for these years was used in the testing process, which resulted in a test set of 20 NRCS forecasts. In addition to these 20 sets of data, each dataset was run three times, using a different number of “similar year” values for each run. The testing matrix for this study is outlined in **table 2**.

**Table 2. Proposed testing matrix for validation of Forecast Model**

Test case	Year	Similar years	Type of snowpack	Number of tests	Comment
1	1995	1	Average	5 (Jan-May)	Test model for most probable runoff volume using the closest year for each NRCS forecast published that year
2	1996	1	Low	5 (Jan-May)	" "
3	1997	1	High	5 (Jan-May)	" "
4	1998	1	Average to low	5 (Jan-May)	" "
5	1995	2	Average	5 (Jan-May)	Test model for most probable runoff volume using the 2 closest years for each NRCS forecast published that year
6	1996	2	Low	5 (Jan-May)	" "
7	1997	2	High	5 (Jan-May)	" "
8	1998	2	Average to low	5 (Jan-May)	" "
9	1995	5	Average	5 (Jan-May)	Test model for most probable runoff volume using the 5 closest years for each NRCS forecast published that year
10	1996	5	Low	5 (Jan-May)	" "
11	1997	5	High	5 (Jan-May)	" "
12	1998	5	Average to low	5 (Jan-May)	" "

Each of the 11 forecast points used in the model were used in this test, with the exceptions of Embudo Creek at Dixon, Jemez Reservoir inflow, Lobatos, and in some years Rio Blanco at Blanco Diversion and Navajo River at Oso Diversion. As stated earlier, the forecast point Embudo Creek at Dixon was added to the NRCS forecast system this year. Because of this relatively new addition, an estimate of 10,000 acre-feet for the March–July runoff volume for this forecast point was used throughout the testing phase. The forecast point Jemez Reservoir inflow is also a recent addition to the NRCS forecast. After discussing this particular forecast point with NRCS staff, the technical team based an estimate of the March–July runoff volume to be input into the model for this forecast point on the relation:

$$\text{Jemez Reservoir inflow} = \text{Jemez River near Jemez} - \text{estimated losses}$$

where: estimated losses = 3,000 acre-feet in a low runoff year and  
5,000 acre-feet in a high runoff year.

For the Lobatos forecast point, the March–July runoff volume was held at a constant 50,000-acre-feet for this study.

The biggest effect of using estimated values for the two forecast points above Otowi (Lobatos and Embudo Creek at Dixon) is on local inflow forecasts above Otowi. By using estimated volumes at these two forecast points, local inflows are adjusted up or down by the model to compensate for these estimates in order to match the forecast at Otowi.

## 4.0 TEST RESULTS

**Tables 3-14** summarize the results of this study. The tables list NRCS forecasts and modeled forecasts for 8 of the 11 forecast points used in the study. As stated earlier, 2 of the 11 forecast points required by the model were recently added to the NRCS reporting system. As such, methods for estimating these forecast points, Jemez Reservoir inflow and Embudo Creek at Dixon were used, as outlined in the previous section. A constant March–July volume of 50,000 acre-feet was used for the Lobatos forecast point.

To test the Otowi forecast results, the equation shown on **page 11**, computing total local inflows, was rearranged to solve for Otowi:

$$\text{ForecastAtOtowi} = (\text{Total Local Inflow} + (\text{routed}(\text{ForecastAtElVado}) + \text{routed}(\text{ForecastAtLobatos}) + \text{routed}(\text{ForecastAtRedRiver}) + \text{routed}(\text{ForecastAtRioPueblo}) + \text{routed}(\text{ForecastAtEmbudoCreek})) \times \text{adjustment factor}) / \text{adjustment factor}.$$

The forecast results for each forecast point and local inflows were substituted into this equation to solve for the forecast flow at Otowi.

The results for the January–March forecasts are fairly self explanatory. The April and May results, however, should be examined more closely because they show the effect of blending flows during the first 3 forecast days in order to gradually blend big increases between observed and forecast flows. If blending were not used, the results would be similar to the January–March forecasts. Considering that the NRCS forecasts are rounded to the nearest 100, 1000, or 10000 acre-feet, depending on the magnitude of the forecast, these results (even with blending) appear perfectly reasonable.

**Table 3. Forecast Model test results (1 similar year) – 1995 NRCS forecasts**

NRCS forecast	Forecast point	NRCS forecast (KAF)	Model volume (KAF)	Percent difference
January 1, 1995	El Vado Reservoir inflow	250	250	0
	Red River below Fish Hatchery	44	44	0
	Rio Pueblo de Taos below Los Cordovas	45	45	0
	Rio Blanco at Blanco diversion	60	60	0
	Navajo River at Oso diversion	75	75	0
	Otowi	800	799.97	0
	Jemez River near Jemez	50	50	0
	Santa Fe River near Santa Fe	3.0	3.0	0
February 1, 1995	El Vado Reservoir inflow	250	250	0
	Red River below Fish Hatchery	50	50	0
	Rio Pueblo de Taos below Los Cordovas	57	57	0
	Rio Blanco at Blanco diversion	60	60	0
	Navajo River at Oso diversion	75	75	0
	Otowi	820	819.96	0
	Jemez River near Jemez	65	65	0
	Santa Fe River near Santa Fe	6.5	6.5	0
March 1, 1995	El Vado Reservoir inflow	279	279	0
	Red River below Fish Hatchery	54	54	0
	Rio Pueblo de Taos below Los Cordovas	65	65	0
	Rio Blanco at Blanco diversion	64	64	0
	Navajo River at Oso diversion	81	81	0
	Otowi	960	957.5	-0.26
	Jemez River near Jemez	66	65.90	-0.15
	Santa Fe River near Santa Fe	6.5	6.5	0
April 1, 1995	El Vado Reservoir inflow	380.0	376.80	-0.84
	Red River below Fish Hatchery	44.0	43.93	-0.16
	Rio Pueblo de Taos below Los Cordovas	21.0	21.08	0.38
	Rio Blanco at Blanco diversion	72.0	72.0	0
	Navajo River at Oso diversion	92.0	92.0	0
	Otowi	1100.0	1090.4	-0.87
	Jemez River near Jemez	55.0	55.0	0
	Santa Fe River near Santa Fe	4.4	4.4	0
May 1, 1995	El Vado Reservoir inflow	400	398.14	-0.46
	Red River below Fish Hatchery	44	43.81	-0.43
	Rio Pueblo de Taos below Los Cordovas	21	21.18	0.86
	Rio Blanco at Blanco diversion	80	80.0	0
	Navajo River at Oso diversion	100	100.0	0
	Otowi	1250	1247.66	-0.19
	Jemez River near Jemez	70	69.04	-1.37
	Santa Fe River near Santa Fe	5.5	5.49	-0.18

**Table 4. Forecast Model test results (2 similar years) – 1995 NRCS forecasts**

NRCS forecast	Forecast point	NRCS forecast (KAF)	Model volume (KAF)	Percent difference
January 1, 1995	El Vado Reservoir inflow	250	250	0
	Red River below Fish Hatchery	44	44	0
	Rio Pueblo de Taos below Los Cordovas	45	45	0
	Rio Blanco at Blanco diversion	60	60	0
	Navajo River at Oso diversion	75	75	0
	Otowi	800	799.97	0
	Jemez River near Jemez	50	50	0
	Santa Fe River near Santa Fe	3.0	3.0	0
February 1, 1995	El Vado Reservoir inflow	250	250	0
	Red River below Fish Hatchery	50	50	0
	Rio Pueblo de Taos below Los Cordovas	57	57	0
	Rio Blanco at Blanco diversion	60	60	0
	Navajo River at Oso diversion	75	75	0
	Otowi	820	819.96	0
	Jemez River near Jemez	65	65	0
	Santa Fe River near Santa Fe	6.5	6.5	0
March 1, 1995	El Vado Reservoir inflow	279	279	0
	Red River below Fish Hatchery	54	54	0
	Rio Pueblo de Taos below Los Cordovas	65	65	0
	Rio Blanco at Blanco diversion	64	64	0
	Navajo River at Oso diversion	81	81	0
	Otowi	960	958.91	-0.11
	Jemez River near Jemez	66	66	0
	Santa Fe River near Santa Fe	6.5	6.5	0
April 1, 1995	El Vado Reservoir inflow	380.0	378.04	-0.52
	Red River below Fish Hatchery	44.0	43.88	-0.27
	Rio Pueblo de Taos below Los Cordovas	21.0	21.0	0
	Rio Blanco at Blanco diversion	72.0	71.63	-0.51
	Navajo River at Oso diversion	92.0	91.65	-0.38
	Otowi	1100.0	1093.27	-0.61
	Jemez River near Jemez	55.0	55.0	0
	Santa Fe River near Santa Fe	4.4	4.4	0
May 1, 1995	El Vado Reservoir inflow	400	399.09	-0.23
	Red River below Fish Hatchery	44	43.78	-0.50
	Rio Pueblo de Taos below Los Cordovas	21	21.16	0.76
	Rio Blanco at Blanco diversion	80	80.0	0
	Navajo River at Oso diversion	100	100.0	0
	Otowi	1250	1243.65	-0.51
	Jemez River near Jemez	70	69.27	-1.04
	Santa Fe River near Santa Fe	5.5	5.48	-0.36



**Table 5. Forecast Model results (5 similar years) – 1995 NRCS forecasts**

NRCS forecast	Forecast point	NRCS forecast (KAF)	Model volume (KAF)	Percent difference
January 1, 1995	El Vado Reservoir inflow	250	250	0
	Red River below Fish Hatchery	44	44	0
	Rio Pueblo de Taos below Los Cordovas	45	45	0
	Rio Blanco at Blanco diversion	60	60	0
	Navajo River at Oso diversion	75	75	0
	Otowi	800	799.96	0
	Jemez River near Jemez	50	50	0
	Santa Fe River near Santa Fe	3.0	3.0	0
February 1, 1995	El Vado Reservoir inflow	250	250	0
	Red River below Fish Hatchery	50	50	0
	Rio Pueblo de Taos below Los Cordovas	57	57	0
	Rio Blanco at Blanco diversion	60	60	0
	Navajo River at Oso diversion	75	75	0
	Otowi	820	819.96	0
	Jemez River near Jemez	65	65	0
	Santa Fe River near Santa Fe	6.5	6.5	0
March 1, 1995	El Vado Reservoir inflow	279	278.90	0
	Red River below Fish Hatchery	54	54	0
	Rio Pueblo de Taos below Los Cordovas	65	65	0
	Rio Blanco at Blanco diversion	64	64	0
	Navajo River at Oso diversion	81	81	0
	Otowi	960	959.11	-0.10
	Jemez River near Jemez	66	66	0
	Santa Fe River near Santa Fe	6.5	6.5	0
April 1, 1995	El Vado Reservoir inflow	380.0	379.19	-0.21
	Red River below Fish Hatchery	44.0	44.0	0
	Rio Pueblo de Taos below Los Cordovas	21.0	21.10	-0.48
	Rio Blanco at Blanco diversion	72.0	71.84	-0.22
	Navajo River at Oso diversion	92.0	91.83	-0.18
	Otowi	1100.0	1096.06	-0.36
	Jemez River near Jemez	55.0	55.0	0
	Santa Fe River near Santa Fe	4.4	4.42	0.45
May 1, 1995	El Vado Reservoir inflow	400	399.01	-0.25
	Red River below Fish Hatchery	44	43.81	-0.43
	Rio Pueblo de Taos below Los Cordovas	21	21.20	0.95
	Rio Blanco at Blanco diversion	80	79.69	-0.39
	Navajo River at Oso diversion	100	100.0	0
	Otowi	1250	1242.67	-0.59
	Jemez River near Jemez	70	69.24	-1.10
	Santa Fe River near Santa Fe	5.5	5.45	-0.91

**Table 6. Forecast Model test results – 1996 NRCS forecasts**

NRCS forecast	Forecast point	NRCS forecast (KAF)	Model volume (KAF)	Percent difference
January 1, 1996	El Vado Reservoir inflow	85.0	85.0	0
	Red River below Fish Hatchery	15.0	15.0	0
	Rio Pueblo de Taos below Los Cordovas	6.0	6.0	0
	Rio Blanco at Blanco diversion	25.0	25.0	0
	Navajo River at Oso diversion	30.0	30.0	0
	Otowi	245.0	244.99	0
	Jemez River near Jemez	17.0	17.0	0
	Santa Fe River near Santa Fe	2.5	2.5	0
February 1, 1996	El Vado Reservoir inflow	100.0	100.0	0
	Red River below Fish Hatchery	20.0	20.0	0
	Rio Pueblo de Taos below Los Cordovas	19.0	19.0	0
	Rio Blanco at Blanco diversion	30.0	30.0	0
	Navajo River at Oso diversion	35.0	35.0	0
	Otowi	270.0	269.99	0
	Jemez River near Jemez	18.0	18.0	0
	Santa Fe River near Santa Fe	2.5	2.5	0
March 1, 1996	El Vado Reservoir inflow	100.0	100.14	0.14
	Red River below Fish Hatchery	18.0	18.0	0
	Rio Pueblo de Taos below Los Cordovas	9.0	9.0	0
	Rio Blanco at Blanco diversion	30.0	30.0	0
	Navajo River at Oso diversion	35.0	35.0	0
	Otowi	270.0	270.37	0.14
	Jemez River near Jemez	14.0	14.0	0
	Santa Fe River near Santa Fe	1.5	1.5	0
April 1, 1996	El Vado Reservoir inflow	91.0	91.17	0.19
	Red River below Fish Hatchery	14.0	14.04	0.29
	Rio Pueblo de Taos below Los Cordovas	6.8	6.83	0.44
	Rio Blanco at Blanco diversion	25.0	25.0	0
	Navajo River at Oso diversion	30.0	30.0	0
	Otowi	230.0	230.45	0.20
	Jemez River near Jemez	10.0	10.0	0
	Santa Fe River near Santa Fe	1.2	1.21	0.83
May 1, 1996	El Vado Reservoir inflow	65.0	66.06	1.63
	Red River below Fish Hatchery	13.0	13.05	0.38
	Rio Pueblo de Taos below Los Cordovas	6.8	6.83	0.44
	Rio Blanco at Blanco diversion	25.0	25.27	1.08
	Navajo River at Oso diversion	30.0	30.21	0.70
	Otowi	200.0	202.27	1.14
	Jemez River near Jemez	9.0	8.91	-1.0
	Santa Fe River near Santa Fe	1.0	1.02	2.00

**Table 7. Forecast Model test results (2 similar years) – 1996 NRCS forecasts**

NRCS forecast	Forecast point	NRCS forecast (KAF)	Model volume (KAF)	Percent difference
January 1, 1996	El Vado Reservoir inflow	85.0	85.0	0
	Red River below Fish Hatchery	15.0	15.0	0
	Rio Pueblo de Taos below Los Cordovas	6.0	6.0	0
	Rio Blanco at Blanco diversion	25.0	25.0	0
	Navajo River at Oso diversion	30.0	30.0	0
	Otowi	245.0	244.99	0
	Jemez River near Jemez	17.0	17.0	0
	Santa Fe River near Santa Fe	2.5	2.5	0
February 1, 1996	El Vado Reservoir inflow	100.0	100.0	0
	Red River below Fish Hatchery	20.0	20.0	0
	Rio Pueblo de Taos below Los Cordovas	19.0	19.0	0
	Rio Blanco at Blanco diversion	30.0	30.0	0
	Navajo River at Oso diversion	35.0	35.0	0
	Otowi	270.0	269.99	0
	Jemez River near Jemez	18.0	18.0	0
	Santa Fe River near Santa Fe	2.5	2.5	0
March 1, 1996	El Vado Reservoir inflow	100.0	99.88	-0.12
	Red River below Fish Hatchery	18.0	18.0	0
	Rio Pueblo de Taos below Los Cordovas	9.0	9.0	0
	Rio Blanco at Blanco diversion	30.0	30.0	0
	Navajo River at Oso diversion	35.0	35.0	0
	Otowi	270.0	270.56	0.21
	Jemez River near Jemez	14.0	14.0	0
	Santa Fe River near Santa Fe	1.5	1.5	0
April 1, 1996	El Vado Reservoir inflow	91.0	90.75	-0.27
	Red River below Fish Hatchery	14.0	14.03	0.21
	Rio Pueblo de Taos below Los Cordovas	6.8	6.8	0
	Rio Blanco at Blanco diversion	25.0	25.0	0
	Navajo River at Oso diversion	30.0	30.0	0
	Otowi	230.0	229.80	0
	Jemez River near Jemez	10.0	10.0	0
	Santa Fe River near Santa Fe	1.2	1.21	0.83
May 1, 1996	El Vado Reservoir inflow	65.0	66.18	1.82
	Red River below Fish Hatchery	13.0	13.03	0.23
	Rio Pueblo de Taos below Los Cordovas	6.8	6.8	0
	Rio Blanco at Blanco diversion	25.0	25.25	1.0
	Navajo River at Oso diversion	30.0	30.19	0.63
	Otowi	200.0	201.72	0.86
	Jemez River near Jemez	9.0	8.87	-1.44
	Santa Fe River near Santa Fe	1.0	1.02	2.00

**Table 8. Forecast Model test results (5 similar years) – 1996 NRCS forecasts**

NRCS forecast	Forecast point	NRCS forecast (KAF)	Model volume (KAF)	Percent difference
January 1, 1996	El Vado Reservoir inflow	85.0	85.0	0
	Red River below Fish Hatchery	15.0	15.0	0
	Rio Pueblo de Taos below Los Cordovas	6.0	6.0	0
	Rio Blanco at Blanco diversion	25.0	25.0	0
	Navajo River at Oso diversion	30.0	30.0	0
	Otowi	245.0	244.99	0
	Jemez River near Jemez	17.0	17.0	0
	Santa Fe River near Santa Fe	2.5	2.5	0
February 1, 1996	El Vado Reservoir inflow	100.0	100.0	0
	Red River below Fish Hatchery	20.0	20.0	0
	Rio Pueblo de Taos below Los Cordovas	19.0	19.0	0
	Rio Blanco at Blanco diversion	30.0	30.0	0
	Navajo River at Oso diversion	35.0	35.0	0
	Otowi	270.0	269.99	0
	Jemez River near Jemez	18.0	18.0	0
	Santa Fe River near Santa Fe	2.5	2.5	0
March 1, 1996	El Vado Reservoir inflow	100.0	99.88	-0.12
	Red River below Fish Hatchery	18.0	18.0	0
	Rio Pueblo de Taos below Los Cordovas	9.0	9.0	0
	Rio Blanco at Blanco diversion	30.0	30.0	0
	Navajo River at Oso diversion	35.0	35.0	0
	Otowi	270.0	270.56	0.21
	Jemez River near Jemez	14.0	14.0	0
	Santa Fe River near Santa Fe	1.5	1.5	0
April 1, 1996	El Vado Reservoir inflow	91.0	91.0	0
	Red River below Fish Hatchery	14.0	14.05	0.36
	Rio Pueblo de Taos below Los Cordovas	6.8	6.85	0.74
	Rio Blanco at Blanco diversion	25.0	25.10	0.40
	Navajo River at Oso diversion	30.0	30.08	0.27
	Otowi	230.0	230.47	0.20
	Jemez River near Jemez	10.0	10.0	0
	Santa Fe River near Santa Fe	1.2	1.22	1.7
May 1, 1996	El Vado Reservoir inflow	65.0	65.74	1.13
	Red River below Fish Hatchery	13.0	13.03	0.23
	Rio Pueblo de Taos below Los Cordovas	6.8	6.82	0.29
	Rio Blanco at Blanco diversion	25.0	25.21	0.84
	Navajo River at Oso diversion	30.0	30.21	0.70
	Otowi	200.0	201.14	0.57
	Jemez River near Jemez	9.0	8.89	-1.22
	Santa Fe River near Santa Fe	1.0	1.02	2.0

**Table 9. Forecast Model test results – 1997 NRCS forecasts**

NRCS forecast	Forecast point	NRCS forecast (KAF)	Model volume (KAF)	Percent difference
January 1, 1997	El Vado Reservoir inflow	280	280	0
	Red River below Fish Hatchery	50	50	0
	Rio Pueblo de Taos below Los Cordovas	56	56	0
	Rio Blanco at Blanco diversion	65	65	0
	Navajo River at Oso diversion	80	80	0
	Otowi	900	899.96	0
	Jemez River near Jemez	50	50	0
	Santa Fe River near Santa Fe	5.4	5.4	0
February 1, 1997	El Vado Reservoir inflow	350	350	0
	Red River below Fish Hatchery	53	53	0
	Rio Pueblo de Taos below Los Cordovas	30	30	0
	Rio Blanco at Blanco diversion	75	75	0
	Navajo River at Oso diversion	95	95	0
	Otowi	1175	1174.95	0
	Jemez River near Jemez	60	60	0
	Santa Fe River near Santa Fe	6.5	6.5	0
March 1, 1997	El Vado Reservoir inflow	340	340.17	0.05
	Red River below Fish Hatchery	50	49.91	-0.18
	Rio Pueblo de Taos below Los Cordovas	26	26	0
	Rio Blanco at Blanco diversion	80	80	0
	Navajo River at Oso diversion	95	95	0
	Otowi	1125	1123.01	-0.18
	Jemez River near Jemez	60	60	0
	Santa Fe River near Santa Fe	5.5	5.5	0
April 1, 1997	El Vado Reservoir inflow	250.0	251.08	0.72
	Red River below Fish Hatchery	33.0	33.0	0
	Rio Pueblo de Taos below Los Cordovas	32.0	32.0	0
	Rio Blanco at Blanco diversion	70.0	69.42	-0.83
	Navajo River at Oso diversion	85.0	85.0	0
	Otowi	850.0	848.72	-0.15
	Jemez River near Jemez	37.0	37.39	1.05
	Santa Fe River near Santa Fe	4.5	4.47	-0.67
May 1, 1997	El Vado Reservoir inflow	260.0	260.02	0
	Red River below Fish Hatchery	37.0	37.0	0
	Rio Pueblo de Taos below Los Cordovas	40.0	40.08	0.20
	Rio Blanco at Blanco diversion	25.0	25.12	0.48
	Navajo River at Oso diversion	30.0	30.22	0.73
	Otowi	955.0	954.66	-0.04
	Jemez River near Jemez	43.0	43.0	0
	Santa Fe River near Santa Fe	4.5	4.5	0

**Table 10. Forecast Model test results (2 similar years) – 1997 NRCS forecasts**

NRCS forecast	Forecast point	NRCS forecast (KAF)	Model volume (KAF)	Percent difference
January 1, 1997	El Vado Reservoir inflow	280	280	0
	Red River below Fish Hatchery	50	50	0
	Rio Pueblo de Taos below Los Cordovas	56	56	0
	Rio Blanco at Blanco diversion	65	65	0
	Navajo River at Oso diversion	80	80	0
	Otowi	900	899.96	0
	Jemez River near Jemez	50	50	0
	Santa Fe River near Santa Fe	5.4	5.4	0
February 1, 1997	El Vado Reservoir inflow	350	350	0
	Red River below Fish Hatchery	53	53	0
	Rio Pueblo de Taos below Los Cordovas	30	30	0
	Rio Blanco at Blanco diversion	75	75	0
	Navajo River at Oso diversion	95	95	0
	Otowi	1175	1174.95	0
	Jemez River near Jemez	60	60	0
	Santa Fe River near Santa Fe	6.5	6.5	0
March 1, 1997	El Vado Reservoir inflow	340	340.24	0.07
	Red River below Fish Hatchery	50	50	0
	Rio Pueblo de Taos below Los Cordovas	26	26	0
	Rio Blanco at Blanco diversion	80	80	0
	Navajo River at Oso diversion	95	95	0
	Otowi	1125	1123.28	-0.15
	Jemez River near Jemez	60	60	0
	Santa Fe River near Santa Fe	5.5	5.5	0
April 1, 1997	El Vado Reservoir inflow	250.0	251.42	0.57
	Red River below Fish Hatchery	33.0	33.0	0
	Rio Pueblo de Taos below Los Cordovas	32.0	32.0	0
	Rio Blanco at Blanco diversion	70.0	69.74	-0.37
	Navajo River at Oso diversion	85.0	85.0	0
	Otowi	850.0	850.61	0.07
	Jemez River near Jemez	37.0	37.27	0.73
	Santa Fe River near Santa Fe	4.5	4.5	0
May 1, 1997	El Vado Reservoir inflow	260.0	256.06	-1.51
	Red River below Fish Hatchery	37.0	37.0	0
	Rio Pueblo de Taos below Los Cordovas	40.0	40.0	0
	Rio Blanco at Blanco diversion	25.0	25.10	0.40
	Navajo River at Oso diversion	30.0	30.20	0.67
	Otowi	955.0	946.35	-0.91
	Jemez River near Jemez	43.0	43.0	0
	Santa Fe River near Santa Fe	4.5	4.49	-0.22

**Table 11. Forecast Model test results (5 similar years) – 1997 NRCS forecasts**

NRCS forecast	Forecast point	NRCS forecast (KAF)	Model volume (KAF)	Percent difference
January 1, 1997	El Vado Reservoir inflow	280	280	0
	Red River below Fish Hatchery	50	50	0
	Rio Pueblo de Taos below Los Cordovas	56	56	0
	Rio Blanco at Blanco diversion	65	65	0
	Navajo River at Oso diversion	80	80	0
	Otowi	900	899.96	0
	Jemez River near Jemez	50	50	0
	Santa Fe River near Santa Fe	5.4	5.4	0
February 1, 1997	El Vado Reservoir inflow	350	350	0
	Red River below Fish Hatchery	53	53	0
	Rio Pueblo de Taos below Los Cordovas	30	30	0
	Rio Blanco at Blanco diversion	75	75	0
	Navajo River at Oso diversion	95	95	0
	Otowi	1175	1174.95	0
	Jemez River near Jemez	60	60	0
	Santa Fe River near Santa Fe	6.5	6.5	0
March 1, 1997	El Vado Reservoir inflow	340	340.24	0.07
	Red River below Fish Hatchery	50	50	0
	Rio Pueblo de Taos below Los Cordovas	26	26	0
	Rio Blanco at Blanco diversion	80	80	0
	Navajo River at Oso diversion	95	95	0
	Otowi	1125	1123.34	-0.15
	Jemez River near Jemez	60	60	0
	Santa Fe River near Santa Fe	5.5	5.5	0
April 1, 1997	El Vado Reservoir inflow	250.0	251.48	0.59
	Red River below Fish Hatchery	33.0	33.0	0
	Rio Pueblo de Taos below Los Cordovas	32.0	32.0	0
	Rio Blanco at Blanco diversion	70.0	70.0	0
	Navajo River at Oso diversion	85.0	85.0	0
	Otowi	850.0	850.85	0.10
	Jemez River near Jemez	37.0	37.27	0.73
	Santa Fe River near Santa Fe	4.5	4.5	0
May 1, 1997	El Vado Reservoir inflow	260.0	257.22	-1.07
	Red River below Fish Hatchery	37.0	36.83	-0.46
	Rio Pueblo de Taos below Los Cordovas	40.0	39.66	-0.85
	Rio Blanco at Blanco diversion	25.0	25.0	0
	Navajo River at Oso diversion	30.0	30.22	0.73
	Otowi	955.0	945.0	-1.05
	Jemez River near Jemez	43.0	43.0	0
	Santa Fe River near Santa Fe	4.5	4.46	-0.89

**Table 12. Forecast Model test results (1 similar year) – 1998 NRCS forecasts**

NRCS forecast	Forecast point	NRCS forecast (KAF)	Model volume (KAF)	Percent difference
January 1, 1998	El Vado Reservoir inflow	240	240	0
	Red River below Fish Hatchery	39	39	0
	Rio Pueblo de Taos below Los Cordovas	20	20	0
	Rio Blanco at Blanco diversion	54	54	0
	Navajo River at Oso diversion	65	65	0
	Otowi	780	779.97	0
	Jemez River near Jemez	51	51	0
	Santa Fe River near Santa Fe	5.5	5.5	0
February 1, 1998	El Vado Reservoir inflow	210	210	0
	Red River below Fish Hatchery	33	33	0
	Rio Pueblo de Taos below Los Cordovas	38	38	0
	Rio Blanco at Blanco diversion	50	50	0
	Navajo River at Oso diversion	60	60	0
	Otowi	700	799.97	0
	Jemez River near Jemez	51	51	0
	Santa Fe River near Santa Fe	4.3	4.3	0
March 1, 1998	El Vado Reservoir inflow	180	179.96	-0.02
	Red River below Fish Hatchery	33	33	0
	Rio Pueblo de Taos below Los Cordovas	17.5	17.5	0
	Rio Blanco at Blanco diversion	45	45	0
	Navajo River at Oso diversion	53	53	0
	Otowi	560	560	0
	Jemez River near Jemez	51	51	0
	Santa Fe River near Santa Fe	4.3	4.3	0
April 1, 1998	El Vado Reservoir inflow	185.0	185.42	0.23
	Red River below Fish Hatchery	35.0	35.0	0
	Rio Pueblo de Taos below Los Cordovas	18.0	18.0	0
	Rio Blanco at Blanco diversion	45.0	45.0	0
	Navajo River at Oso diversion	55.0	55.0	0
	Otowi	580.0	580.37	0.06
	Jemez River near Jemez	40.0	39.63	-0.93
	Santa Fe River near Santa Fe	5.0	5.0	0
May 1, 1998	El Vado Reservoir inflow	200.0	196.53	-1.74
	Red River below Fish Hatchery	36.0	35.70	-0.83
	Rio Pueblo de Taos below Los Cordovas	38.0	37.14	-2.26
	Rio Blanco at Blanco diversion	50.0	50.20	0.40
	Navajo River at Oso diversion	60.0	60.22	0.37
	Otowi	680.0	673.45	-0.96
	Jemez River near Jemez	40.0	40.0	0
	Santa Fe River near Santa Fe	6.0	5.87	-2.17



**Table 13. Forecast Model test results (2 similar years) – 1998 NRCS forecasts**

NRCS forecast	Forecast point	NRCS forecast (KAF)	Model volume (KAF)	Percent difference
January 1, 1998	El Vado Reservoir inflow	240	240	0
	Red River below Fish Hatchery	39	39	0
	Rio Pueblo de Taos below Los Cordovas	20	20	0
	Rio Blanco at Blanco diversion	54	54	0
	Navajo River at Oso diversion	65	65	0
	Otowi	780	779.97	0
	Jemez River near Jemez	51	51	0
	Santa Fe River near Santa Fe	5.5	5.5	0
February 1, 1998	El Vado Reservoir inflow	210	210	0
	Red River below Fish Hatchery	33	33	0
	Rio Pueblo de Taos below Los Cordovas	38	38	0
	Rio Blanco at Blanco diversion	50	50	0
	Navajo River at Oso diversion	60	60	0
	Otowi	700	699.97	0
	Jemez River near Jemez	51	51	0
	Santa Fe River near Santa Fe	4.3	4.3	0
March 1, 1998	El Vado Reservoir inflow	180	179.86	-0.08
	Red River below Fish Hatchery	33	33	0
	Rio Pueblo de Taos below Los Cordovas	17.5	17.5	0
	Rio Blanco at Blanco diversion	45	45	0
	Navajo River at Oso diversion	53	53	0
	Otowi	560	559.22	-0.14
	Jemez River near Jemez	51	51	0
	Santa Fe River near Santa Fe	4.3	4.3	0
April 1, 1998	El Vado Reservoir inflow	185.0	184.69	-0.17
	Red River below Fish Hatchery	35.0	34.91	-0.26
	Rio Pueblo de Taos below Los Cordovas	18.0	18.0	0
	Rio Blanco at Blanco diversion	45.0	45.0	0
	Navajo River at Oso diversion	55.0	55.0	0
	Otowi	580.0	578.61	-0.24
	Jemez River near Jemez	40.0	40.0	0
	Santa Fe River near Santa Fe	5.0	5.0	0
May 1, 1998	El Vado Reservoir inflow	200.0	195.32	-2.34
	Red River below Fish Hatchery	36.0	35.87	-0.36
	Rio Pueblo de Taos below Los Cordovas	38.0	37.62	-1.0
	Rio Blanco at Blanco diversion	50.0	50.0	0
	Navajo River at Oso diversion	60.0	60.0	0
	Otowi	680.0	670.49	-1.40
	Jemez River near Jemez	40.0	40.0	0
	Santa Fe River near Santa Fe	6.0	5.92	-1.33

**Table 14. Forecast Model test results (5 similar years) – 1998 NRCS forecasts**

NRCS forecast	Forecast point	NRCS forecast (KAF)	Model volume (KAF)	Percent difference
January 1, 1998	El Vado Reservoir inflow	240	240	0
	Red River below Fish Hatchery	39	39	0
	Rio Pueblo de Taos below Los Cordovas	20	20	0
	Rio Blanco at Blanco diversion	54	54	0
	Navajo River at Oso diversion	65	65	0
	Otowi	780	779.97	0
	Jemez River near Jemez	51	51	0
	Santa Fe River near Santa Fe	5.5	5.5	0
February 1, 1998	El Vado Reservoir inflow	210	210	0
	Red River below Fish Hatchery	33	33	0
	Rio Pueblo de Taos below Los Cordovas	38	38	0
	Rio Blanco at Blanco diversion	50	50	0
	Navajo River at Oso diversion	60	60	0
	Otowi	700	669.97	0
	Jemez River near Jemez	51	51	0
	Santa Fe River near Santa Fe	4.3	4.3	0
March 1, 1998	El Vado Reservoir inflow	180	179.95	-0.03
	Red River below Fish Hatchery	33	33	0
	Rio Pueblo de Taos below Los Cordovas	17.5	17.5	0
	Rio Blanco at Blanco diversion	45	45	0
	Navajo River at Oso diversion	53	53	0
	Otowi	560	559.62	-0.07
	Jemez River near Jemez	51	51	0
	Santa Fe River near Santa Fe	4.3	4.3	0
April 1, 1998	El Vado Reservoir inflow	185.0	185.05	0.03
	Red River below Fish Hatchery	35.0	35.0	0
	Rio Pueblo de Taos below Los Cordovas	18.0	18.04	0.22
	Rio Blanco at Blanco diversion	45.0	45.0	0
	Navajo River at Oso diversion	55.0	55.0	0
	Otowi	580.0	580.07	0.01
	Jemez River near Jemez	40.0	40.0	0
	Santa Fe River near Santa Fe	5.0	5.01	0.20
May 1, 1998	El Vado Reservoir inflow	200.0	199.77	-0.12
	Red River below Fish Hatchery	36.0	35.87	-0.36
	Rio Pueblo de Taos below Los Cordovas	38.0	37.58	-1.11
	Rio Blanco at Blanco diversion	50.0	50.0	0
	Navajo River at Oso diversion	60.0	60.0	0
	Otowi	680.0	675.29	-0.69
	Jemez River near Jemez	40.0	40.0	0
	Santa Fe River near Santa Fe	6.0	5.95	-0.83

## **5.0 CONCLUSION**

The Forecast Model adequately maintains the NRCS forecast volume for each forecast point when disaggregating the runoff period volume to generate daily flow values for use in other models. The difference between the NRCS and Model forecast for all forecast points for all tests does not exceed 2.34%. This method of forecasting flows may eventually be replaced by other methods, such as MMS or CWMS, but may still be needed in the future for forecasting other parameters, such as diversions, drain flows, wastewater returns, precipitation, etc.

The Forecast Model gives the user a fair amount of flexibility in generating forecast values, but it also requires the user to verify that the model produced the desired results. As with any computer model, the Forecast Model is a tool to be used by experienced individuals, particularly for water-resources uses.